

DIET OF LARVAL AND JUVENILE
BLACK BREAM, *ACANTHOPAGRUS BUTCHERI*,
IN THE HOPKINS RIVER ESTUARY, VICTORIA, AUSTRALIA

S. E. WILLIS¹, L. J. B. LAURENSEN¹, B. D. MITCHELL¹ & D. J. HARRINGTON²

¹School of Ecology and Environment, Deakin University, Victoria 3280, Australia

²Department of Natural Resources and Environment, Victoria 3084, Australia

WILLIS, S. E., LAURENSEN, L. J. B., MITCHELL, B. D. & HARRINGTON, D. J., 1999:11:30. Diet of larval and juvenile black bream, *Acanthopagrus butcheri*, in the Hopkins River Estuary, Victoria, Australia. *Proceedings of the Royal Society of Victoria* 111(2): 283-295. ISSN 0035-9211.

Stomach contents of larval and juvenile *Acanthopagrus butcheri* from an estuary were studied to determine ontogenetic differences in diet. Evidence of ontogenetic differences in diet strongly linked to ontogenetic changes in habitat preferences was identified. Larvae were found to exclusively utilise pelagic habitats while juveniles settled into fringing weed beds in shallow estuarine waters. Larvae <9 mm in length fed primarily on calanoid copepod nauplii. Larvae >9 mm consumed mainly calanoid copepodites and unidentified fish larvae. The most important diet items for juveniles <40 mm in length were calanoid copepods, particularly *Gladioferens pectinatus* and *Sulcanus conflictus*. With increasing size (>20-40 mm to >40-60 mm), copepods became less important in the diet and were replaced by amphipods, gastropods and polychaetes, reflecting a shift from feeding in the water column to feeding in weed-beds. Polychaetes were the main food types consumed by juveniles >60 mm in length. The diverse range of food types found in stomachs illustrates the flexible and opportunistic nature of feeding in juvenile *A. butcheri*.

THE use of estuaries as nursery grounds by many species of fish has been well documented in Australia (Blaber & Blaber 1980; Blaber 1980; Potter 1983; Russel 1983). Most of the important species taken in recreational and commercial fisheries in Australia depend on estuaries for part or all of their life histories (Lenanton 1987; Pollard 1976). The Hopkins River is one of many south-western Victorian estuaries, which support a diverse and substantial recreational fishery, of which the black bream *Acanthopagrus butcheri* forms a very important component (McCarragher 1986). *Acanthopagrus butcheri* spends its entire life-cycle in estuaries (Lenanton 1987), and is thus likely to have evolved adaptive mechanisms to cope with the physiological stress imposed by the estuarine environment and to reduce competition between age classes. Ontogenetic shifts in diet and/or habitat occupied are mechanisms used in other lacustrine and estuarine fishes to reduce intraspecific competition (Blaber & Blaber 1980; Chrystal 1985; Day 1989; Russel 1983).

Acanthopagrus butcheri are believed to spawn in waters with salinities ranging between 11 and 18 ppt (Butcher 1945). Aggregations of ripe and spent adult *A. butcheri* are observed in the Hopkins River Estuary from September to October with the exact time of spawning depending on seasonal fluctuations in river discharge (Sherwood 1982). *Acanthopagrus butcheri* larvae are planktonic being

readily caught in the water column; juveniles occupy littoral weed beds where they constitute the smallest size class in the juvenile bream population. The size at which this habitat shift occurs has not been determined. The survival rate of a larval cohort is influenced by the level of predation, the availability of resources (eg. space, food, refugia) and, subsequently, the extent and efficiency of resource partitioning to reduce intra-specific competition between juveniles. Ontogenetic shifts in diet of larval and juvenile *A. butcheri* have not been determined.

There are no published studies describing the feeding habits of juvenile *A. butcheri*. Weng (1970) reported 'no indication that the diet of small fish is different from that of adults'. However, Weng's study did not include fish <15 cm in length. The present study was undertaken to describe the diets of larval and juvenile *A. butcheri*, to examine the nature of ontogenetic changes in diet during the early stages of life, and to attempt to identify the size at which larvae leave the water column and enter the weed beds.

METHODS

Study area

The Hopkins River rises in the Great Dividing Range, north-east of Ararat (Fig. 1) and is approx-

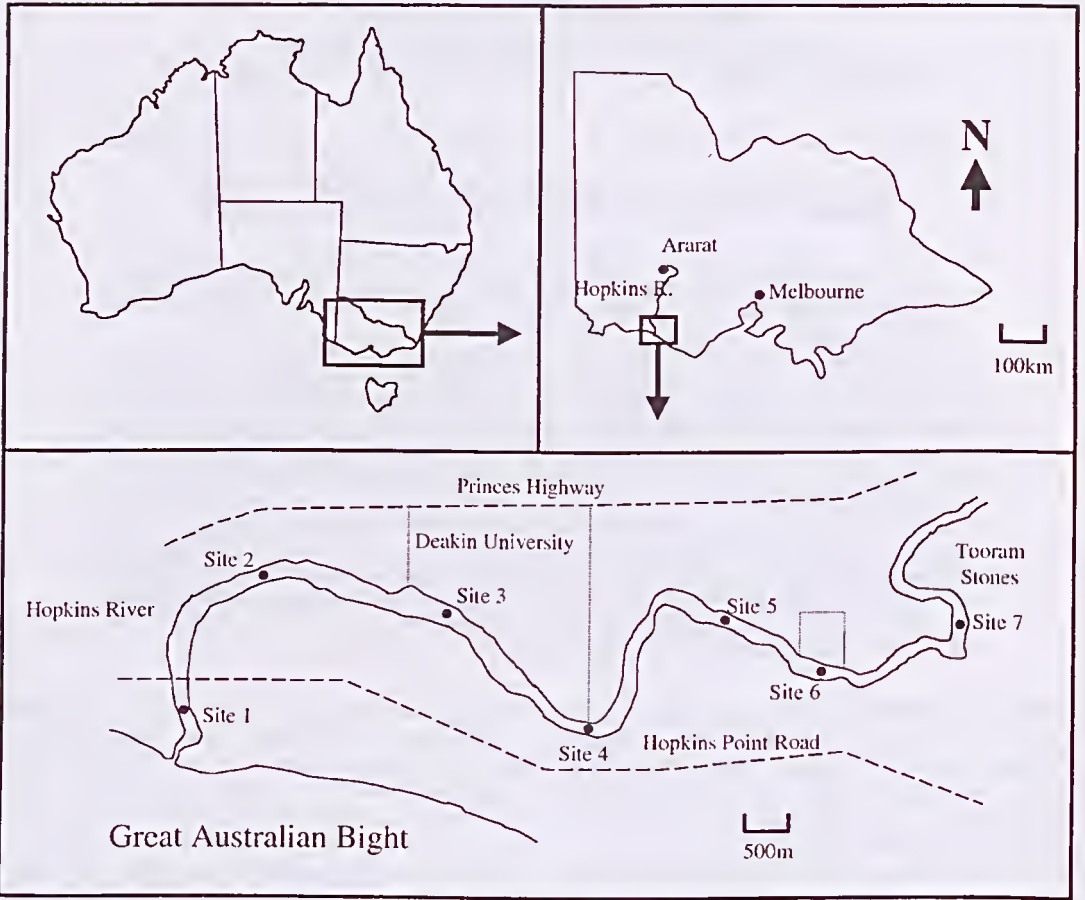


Fig. 1. The Hopkins River Estuary, western Victoria, Australia, showing the location of sampling sites used during the study.

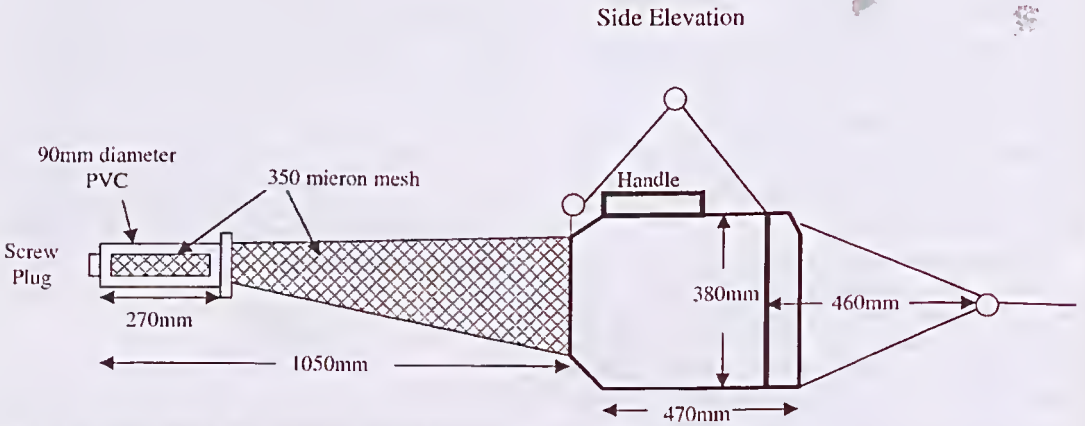


Fig. 2. Side elevation of plankton net used to collect larvae.

imately 170 km in length. The estuary is tidal to Tooram Stones (Site 1, Fig. 1), approximately 9 km upstream from the mouth of the river (Fig. 1). Sherwood & Baekhouse (1982) have described the hydrodynamics and salinity regime of the Hopkins River Estuary and classified it as a highly stratified salt wedge type system. Discharge above 4 million m³/day during September and October is sufficient to completely flush salt water from the estuary. Re-establishment of the salt wedge characteristically occurs during late spring and early summer. By February, bottom salinities approach that of seawater with an overlying surface layer of brackish water. The halocline is characteristically located at a depth of approximately 2 m at this time (Sherwood & Baekhouse 1982).

Sampling regime

Icthyoplankton samples were collected from sites 1, 2, 4, 6 and 7 (Fig. 1) during the spawning season of 1982 (October, November and December; after Weng (1970)), using a 350 micron mesh plankton net (Fig. 2) towed behind a boat. Plankton tows were carried out between mid-morning and mid-afternoon. All tows lasted for 10 minutes and were directed into the prevailing current at a speed of approximately 2 knots.

Samples of juvenile fish were collected from sites 1 and 2 in early January 1983 and from sites 1, 2, 3, 6 and 7 in late January and late February 1983. Site 5 was only sampled in late January 1983. Samples were collected by dragging a 2 mm mesh seine net measuring 3 m long and 1 m high through *Zostera muelleri* weed beds. All samples were preserved in 5% formalin.

Total length (TL) of all larvae and juveniles was measured as the length from the most anterior point of the snout (with the mouth closed) to the most posterior point of the extended caudal fin. Larval length was measured using a micrometer and binocular microscope; juvenile length was measured using a 400 mm ruler. Total length measurements were rounded to the nearest mm.

Stomach contents were removed and identified using a compound binocular microscope. The relative importance of diet items was enumerated using the rank method (Pollard 1976), in which different diet items are first ranked in order of preponderance according to a subjective estimate of their relative volumes. Each food item is then awarded a 'preponderance score', which is equal to the largest number of food types in any one stomach, plus one, minus the rank. Individual

scores for each food type are then summed over the total number of fish in each size class and expressed as percentages of the sum total score for all food types in fish of a given size class.

The degree of dietary overlap between size classes was calculated using Schoener's Index (S.I.; Schoener 1970).

$$S.I. = 1 - 0.5 \sum_n |P_{xi} - P_{yi}|$$

Where n is the number of food categories, P_{xi} is the proportion (% preponderance) of food item i in the diet of size class x , and P_{yi} is the proportion (% preponderance) of food category i in the diet of size class y (proportions are expressed as decimal fractions). This index gives values from 0 (no overlap) to 1 (complete overlap) and overlap in diet is considered to be biologically significant when the value exceeds 0.6 (after Sloane 1984, citing Wallace 1981).

Salinity (ppt), dissolved oxygen (ppm) and temperature (°C) were measured at all sites using a Yeokal meter at 0.1, 1, 2, 3, 4, 5, 6, 7, 9, 11 and 13 m depth intervals, or until the bottom of the estuary was reached.

RESULTS

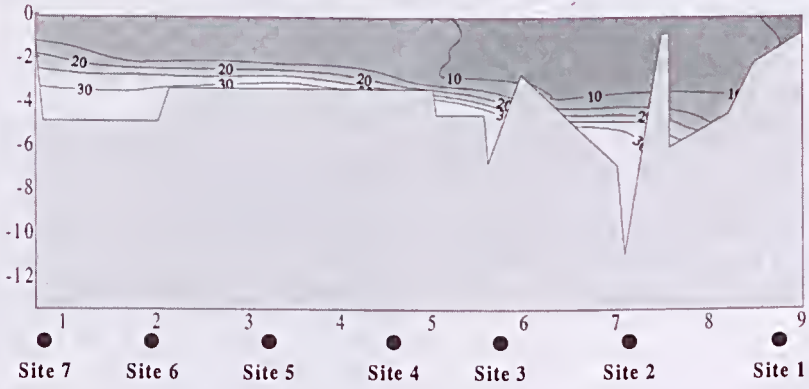
Salinity, dissolved oxygen and temperature

The minimum and maximum salinity levels recorded in the system during the study period were 2.2 ppt (9 m, January, Site 1) and 33.2 ppt (11 m, February, Site 2), respectively (Fig. 3). Contour plots of the salinity profile of the system (Fig. 3) show that a marked halocline was present between 2 and 4 m throughout the study period. The intrusion of late winter freshwater runoff was clearly evident in November, marginally so in January and had completely disappeared by February.

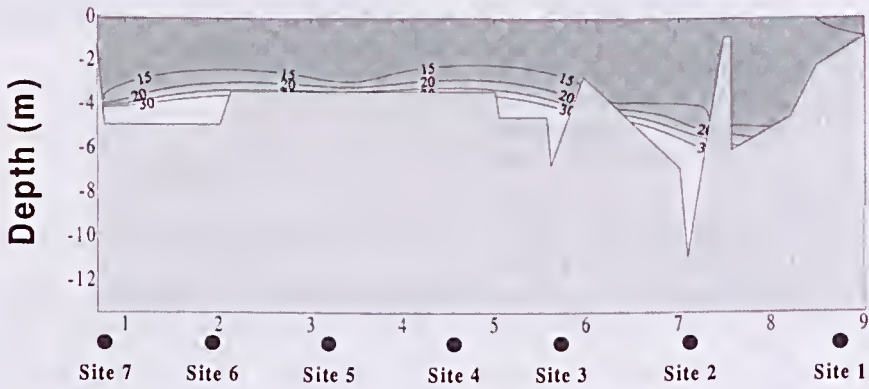
The high degree of stratification found in salinity was also reflected in oxygen levels (Fig. 4). The minimum and maximum oxygen levels recorded in the system during the study period were 0.3 ppm (4 m, November, Site 2 and 6 m, January, Site 2) and 10.2 ppm (1 m, January, Site 1), respectively. Contour plots of dissolved oxygen in the estuary showed those waters deeper than 4 m contained extremely low levels of oxygen throughout the study period at all sites and that those waters deeper than 5 m contained virtually no dissolved oxygen at all (Fig. 4).

Salinity (PPT)

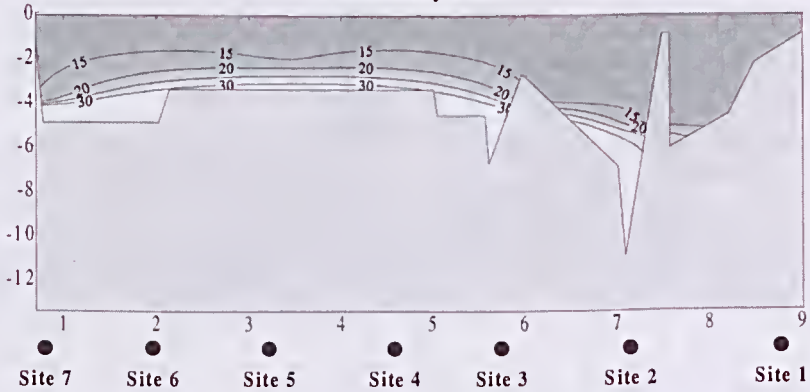
November 1982



January 1982



February 1982



Distance Upstream (km)

Site	Date	Larval length classes (mm)												Total
		3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-10.9	11.0-11.9	12.0-12.9	13.0-13.9	14.0-14.9	
1	26 Nov. 82	48	86	34	16								184	
	8 Dec. 82									10	7	7	24	
2	27 Nov. 82	15	92	180	96	4							387	
	16 Nov. 83		3	11	26	10		2	3		3		58	
4	12 Aug. 82			2									2	
	27 Oct. 82	4	21	73	102	36	5	2	2				245	
6	17 Nov. 82			2	15	32	20	5	3	3	4	2	86	
	27 Oct. 82		7	8	18	9	2	2			2		48	
	17 Nov. 82			2	2	2	2	3	5	3	2		21	

Table 1. Numbers of larval *Acanthopagrus butcheri* in different length classes collected from various sites in the Hopkins River Estuary.

The temperature the water in the estuary ranged from a minimum of 15.2°C (4 m, November, Site 6) to a maximum of 21.75°C (1 m, February, Site 3). Contour plots of the temperature profile of the estuary (Fig. 5) showed a substantial degree of thermal stratification in January and February. In contrast, while thermal stratification was evident during November, it was far less marked than that occurring in January and February. The reduced level of thermal stratification during November was attributed to influx of cooler freshwater from late winter runoff into the estuary and surface heating during the nil water flow periods of January and February.

Ichthyoplankton samples

Larvae were mainly found in the upper and middle estuary (sites 1, 2 and 4), although small numbers were also recorded in the lower estuary. No larvae were collected at Site 7 probably due to high salinity (Fig. 3). The number and length of larval *A. butcheri* collected during the sampling period are shown in Table 1. The number of larvae present in samples decreased over time as they were recruited to the weed-beds and only a small number were collected in December. Few larvae >10 mm were caught in the plankton net.

The stomachs of 283 larval *A. butcheri* were examined and diet items recorded (Table 2). The per cent frequency of the number of diet items found in larval stomachs is shown in Fig. 6. The maximum number of diet items found in any

one larval stomach was 3, however, the majority of the stomachs examined contained only one diet item.

The relative importance of diet items in the two larval size classes, 2.9–9.0 mm and 9.1–14.5 mm, are separately shown in Fig. 7. Larvae belonging to the smaller size class fed almost exclusively on calanoid copepod nauplii with smaller proportions of cyclopod and calanoid copepodites also recorded. In contrast, larvae belonging to the larger size class fed mainly on unidentified fish larvae and calanoid copepodites. The degree of dietary overlap between the two larval size classes ($S.I. = 0.21$) was not biologically significant. Within site comparisons of diet of fish could not be completed from the data collected, as all size classes of fish were not represented at all sites in the estuary (Table 1).

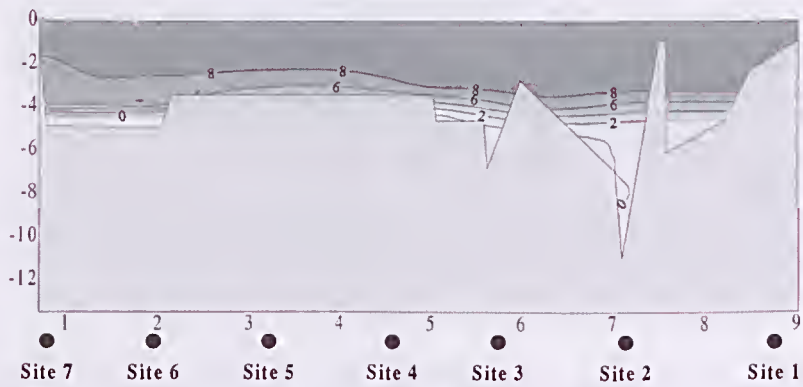
Juvenile samples

The number and length of juvenile *A. butcheri* collected during the sampling period are shown in Table 3. Weng (1970) showed that *A. butcheri* grow to an average TL of 80 mm in their first year, thus the juveniles sampled in this study probably consisted of 0+ and 1+ year classes. Juveniles were divided into four size classes: <20 mm, 20–40 mm, 40–60 mm and >60 mm. The stomachs of 564 juvenile *A. butcheri* were examined and the diet items found are listed in Table 2. The maximum number of food types occurring in any stomach was 8 (Fig. 6), although the majority of stomachs contained only 2 items.

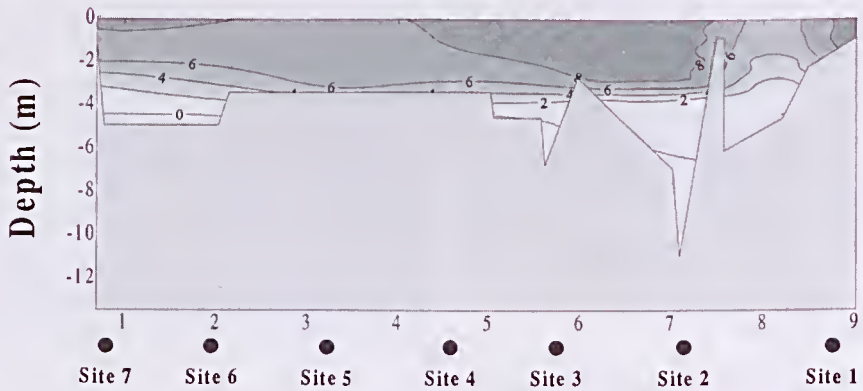
Fig. 3. Salinity profiles of the Hopkins River Estuary between November 1982 and February 1983.

Dissolved Oxygen (PPM)

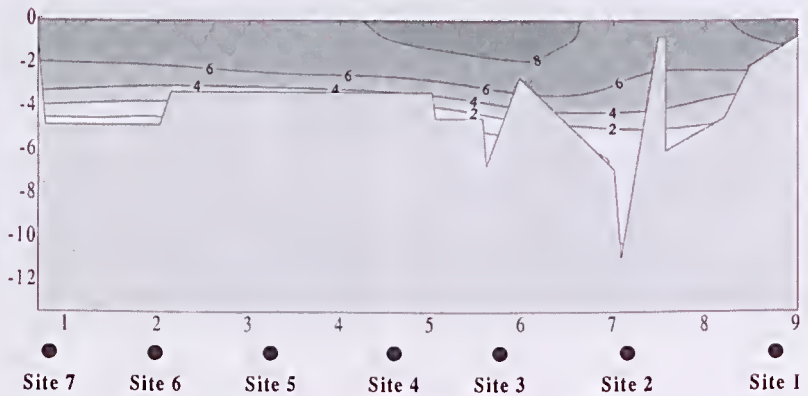
November 1982



January 1983



February 1983



Distance Upstream (km)

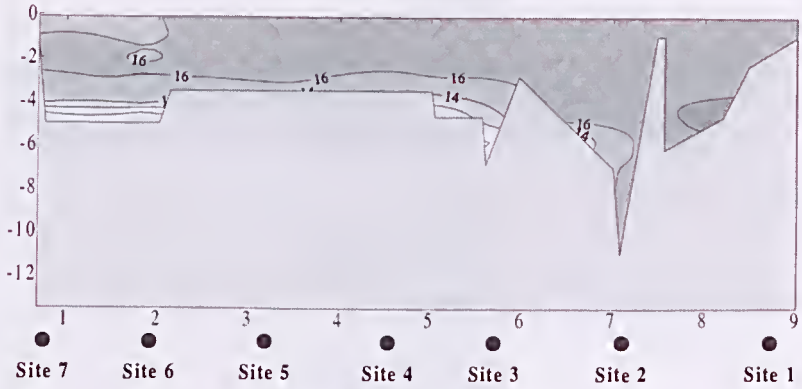
			Larvae	Juveniles	Dominant item
Detritus	Algae	<i>Spirogyra</i> sp.	*	*	
		<i>Lyngbia</i> sp.		*	
		<i>Enteromorpha</i> sp.		*	
		<i>Compsopogon</i> sp.		*	
		Unidentified diatom sp. 1		*	
		Unidentified diatom sp. 2	*	*	
Copepoda	Calanoida	<i>Gippslandia esmarina</i>	*	*	
		<i>Gladioferens pectinatus</i>	*	*	*
		<i>Sulcanus conflictus</i>	*	*	
		Calanoida sp. 1	*		
		Calanoida sp. 2	*		
		Indeterminate Calanoida	*	*	
		Calanoida nauplius 1	*		
		Calanoida nauplius 2	*		
	Cyclopoida	Cyclopoida sp. 1	*		
		Cyclopoida sp. 2	*		
		Cyclopoida sp. 3		*	
		Indeterminate Cyclopoida		*	
		Indeterminate Copepoda	*	*	
		Ostracoda sp. 1		*	
Ostracoda	Ostracoda sp. 2		*		
	Malacostraca	Amphipoda	<i>Paracorophium</i> sp.		*
Corophiidae sp. 1				*	*
<i>Paracalliope</i> sp.				*	
<i>Gammaropsis</i> sp.				*	*
<i>Melita</i> sp.				*	
Amphipoda sp. 2			*		
Indeterminate Amphipoda			*		
Decapoda		<i>Amarinus</i> sp.		*	*
		Grapsidae sp.		*	
		Unidentified zoeae		*	
	Crab remains		*		
	<i>Paratya australiensis</i>		*		
Insecta		<i>Macrobrachium intermedium</i>		*	
		Mysidae		*	
		Trichoptera sp. 1		*	
		Trichoptera sp. 2		*	
		Chironomidae sp.		*	
		Diptera pupa 1		*	
		Diptera pupa 2		*	
		Unidentified Diptera		*	
		Pyralidae		*	
		Gastropoda	Hydrobiidae sp.		*
<i>Hydrobia</i> sp.			*		
Polychaeta		Unidentified Polychaeta		*	
		<i>Ficopotamus enigmaticus</i>		*	
		Capatellidae sp.		*	
Fish		<i>Phyllipnodon grandiceps</i>		*	
		<i>Pseudogobius olorum</i>		*	
		<i>Atherinosoma microstoma</i>		*	
		Unidentified pipefish		*	
		Larva 1		*	
		Larva 2		*	
		Larva 3	*	*	
Indeterminate fish remains		*			
Nematode			*		
Unidentified eggs		*	*		
Miscellaneous			*		

Table 2. Diet items recorded from the stomachs of larval and juvenile *Acanthopagrus butcheri* from the Hopkins River.

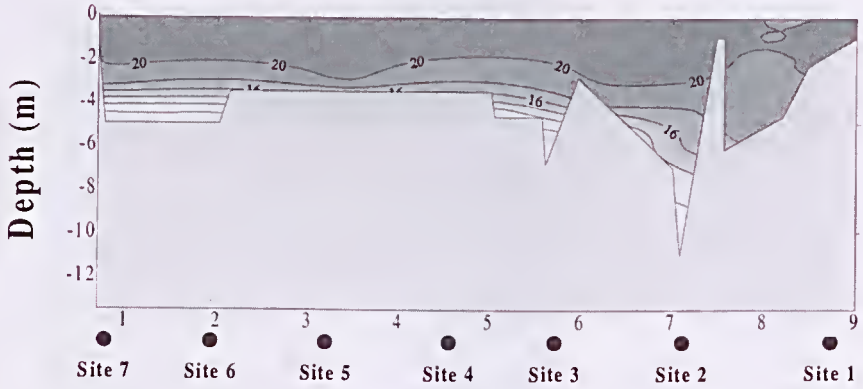
Fig. 4. Dissolved oxygen profiles of the Hopkins River Estuary between November 1982 and February 1983.

Temperature (degrees C)

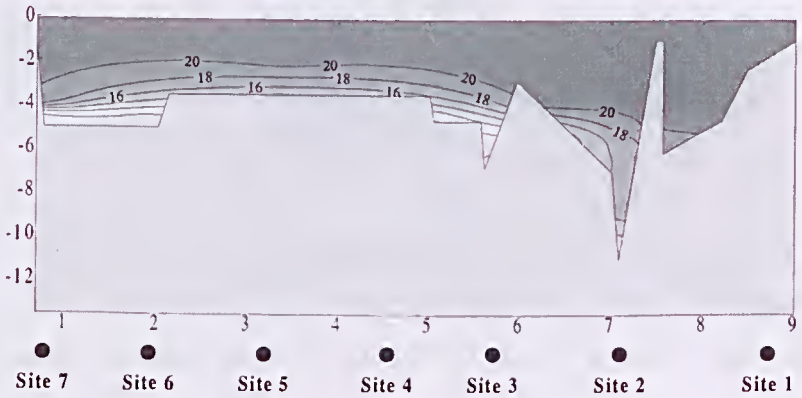
November 1982



January 1983



February 1983



Distance Upstream (km)

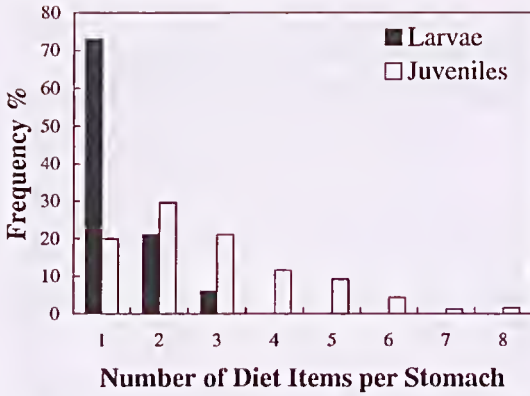


Fig. 6. Frequency distribution of the number of diet items found in the stomachs of larval and juvenile *Acanthopagrus butcheri*.

A total of 59 different food items were recorded from juvenile stomachs. Diet items were classified using the categories given in Table 2.

The relative importance of diet items in the four size classes of juvenile *A. butcheri* is illustrated in Fig. 8. Copepods were the major component of the diet of fish <20 mm and >20–40 mm in length. As fish increased in size, the dietary importance of copepods decreased as amphipods, gastropods and polychaetes became more important. The relative proportion of detritus and algae increased in the stomachs of the larger size classes.

There was little overlap in diet of juvenile *A. butcheri* (all size classes combined) among sites (Table 4). Biologically significant overlap in diet occurred between sites 2 and 3 (S.I. = 0.68), however, the majority of S.I. values were below 0.50. Since there was little overlap in diet of juveniles among sites, diet overlap was examined on a site by site basis to avoid the possibility of site effects biasing the analysis.

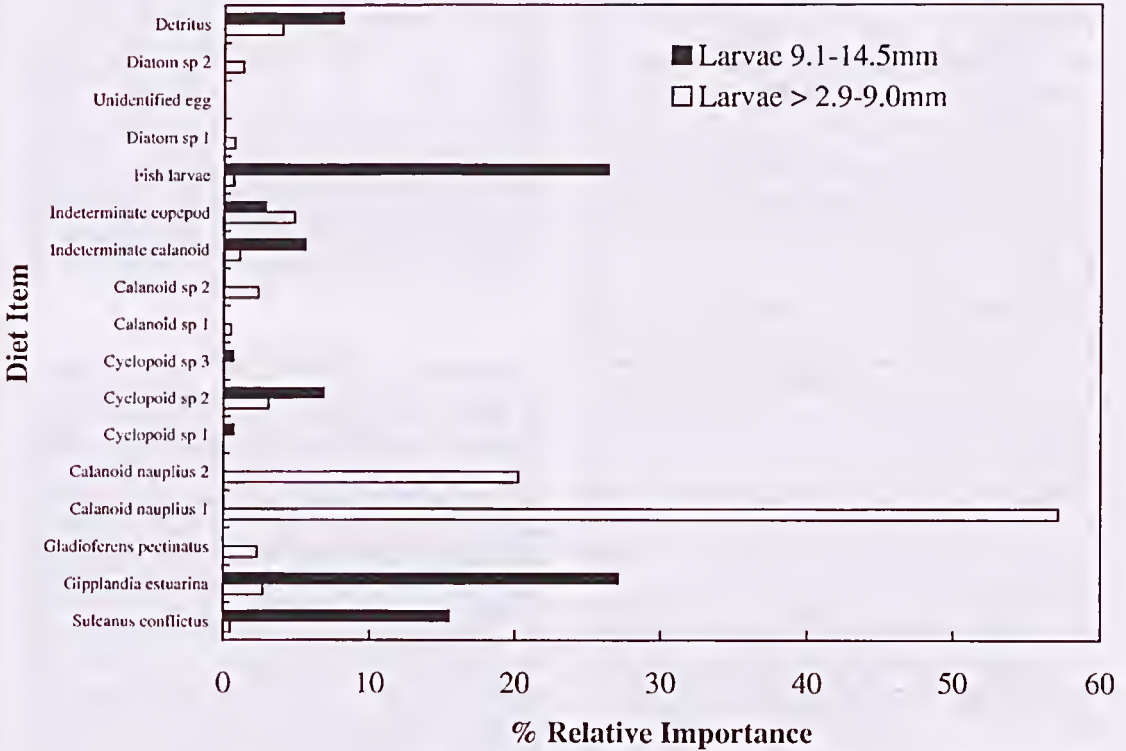


Fig. 7. Relative importance of diet items in the stomachs of larval *Acanthopagrus butcheri* from two size classes (>2.9–9.0 mm and 9.1–14.5 mm).

Fig. 5. Temperature profiles of the Hopkins River Estuary between November 1982 and February 1983.

Site	Date	Larval length classes (mm)												Total
		15.0-	25.0-	35.0-	45.0-	55.0-	65.0-	75.0-	85.0-	95.0-	105.0-	115.0-	125.0-	
		24.9	34.9	44.9	54.9	64.9	74.9	84.9	94.9	104.9	114.9	124.9	134.9	
1	1 May 83	4	5	25	3	2								39
	26 Apr. 83	37	2	10	5	1								55
	23 Feb. 83	3			1									4
2	1 May 83	7	6	7										20
	26 Jan. 83	17	5	2	2	1								27
	23 Feb. 83	9	8	9	11	11	2	1						51
3	26 Jan. 83	51	33	18	16	3	1							122
	23 Feb. 83				14	29	15	1	1					60
5	26 Jan. 83		5	4	10	11								30
6	26 Jan. 83	4	1	4	14	7	3							33
	23 Feb. 83		2	5	14	19	6	3	1					50
7	28 Jan. 83	2		11	12	3		1						29
	23 Feb. 83				6	19	16	6	1					48

Table 3. Numbers of juvenile *Acanthopagrus butcheri* in different length classes collected from various sites in the Hopkins River Estuary.

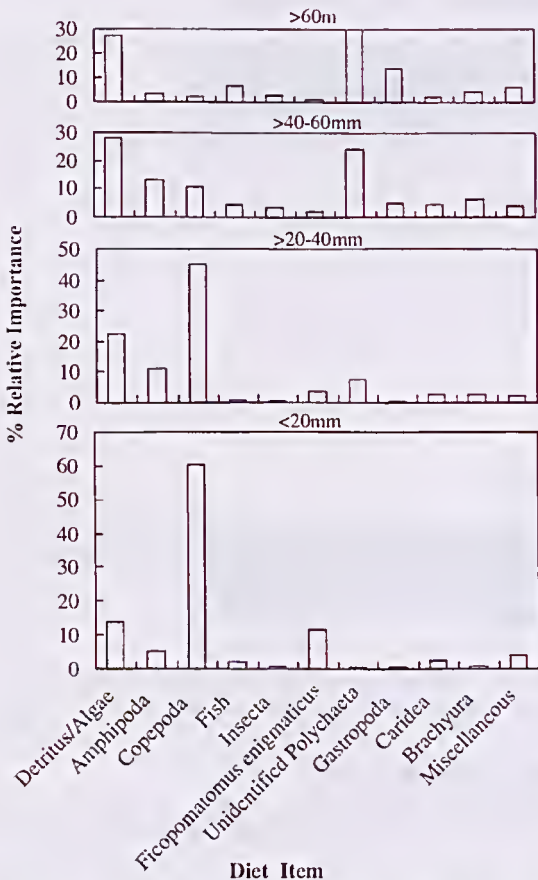


Fig. 8. Relative importance of diet items in the stomachs of four size classes of juvenile *Acanthopagrus butcheri*.

	Site 1	Site 2	Site 3	Site 5	Site 6	Site 7
Site 1	*	0.49	0.48	0.20	0.34	0.32
Site 2	*	*	0.68	0.17	0.29	0.33
Site 3	*	*	*	0.20	0.38	0.48
Site 5	*	*	*	*	0.24	0.39
Site 6	*	*	*	*	*	0.58

Table 4. Schoener's Index of dietary overlap among four size classes of juvenile *Acanthopagrus butcheri* comparing dietary overlap among sites. An overlap of 0.6 or greater is considered biologically significant (i.e. the fish are competing for the same food resources).

Biologically significant diet overlap between different size classes of juveniles occurred at all sites to varying degrees, for example, Site 1 between > 20-40 and > 40-60 mm (S.I. = 0.61) and Site 3 between < 20 and > 20-40 mm (S.I. = 0.82) (Table 5). However, there are more important trends in the data when they are viewed as sequences of S.I. values rather than individually significant results. The degree of overlap of diet of adjacent size classes (eg. < 20 mm and > 20-40 mm) ranges between 0.5 and 0.7, however, the degree of overlap reduces by the order of approximately 50% when S.I.s of non-adjacent size classes are compared. For example, at Site 2 the S.I. values comparing juveniles < 20 mm in length with juveniles > 20-40, > 40-60 and > 60 mm progressively declines from 0.64 to 0.23 to 0.14. This pattern is consistent at all sites and with all comparisons. The trend described above is equally consistent when data from sites are combined (Table 5).

	Size class (mm)	< 20	> 20-40	> 40-60	> 60
Site 1	< 20	*	0.54	0.28	*
	> 20-40	*	*	0.61	*
	> 40-60	*	*	*	*
Site 2	< 20	*	0.64	0.23	0.14
	> 20-40	*	*	0.51	0.36
	> 40-60	*	*	*	0.69
Site 3	< 20	*	0.82	0.41	0.23
	> 20-40	*	*	0.51	0.32
	> 40-60	*	*	*	0.69
Site 5	< 20	*	*	*	*
	> 20-40	*	*	0.63	*
	> 40-60	*	*	*	*
Site 6	< 20	*	*	*	*
	> 20-40	*	*	0.69	0.35
	> 40-60	*	*	*	0.56
Site 7	< 20	*	*	*	*
	> 20-40	*	*	0.46	0.31
	> 40-60	*	*	*	0.72
Sites combined	< 20	*	0.71	0.32	0.22
	> 20-40	*	*	0.55	0.41
	> 40-60	*	*	*	0.69

Table 5. Schoener's Index of dietary overlap among four size classes of juvenile *Acanthopagrus butcheri* from all sites. An overlap of 0.6 or greater is considered biologically significant (ie. the fish are competing for the same food resources).

DISCUSSION

The present study of diet in larval and juvenile *A. butcheri* demonstrated dietary differences between larvae (< 15 mm TL) and juveniles (15 mm TL). Larvae < 9 mm consumed mostly calanoid copepod nauplii, while larvae > 9 mm consumed calanoid copepodites and unidentified fish larvae. This suggested that larvae were feeding in the open water column, a conclusion supported by the lack of larvae collected in weed-beds and the predominance of larvae collected in the water column. The diet of juvenile *A. butcheri* reflects the littoral habitat in which they are found. Larvae < 40 mm in length consumed mostly species of calanoid copepods which tended to be associated with weed beds (G. Newton, Bureau of Rural Resources, Canberra, pers. comm.), while larger juveniles consumed mostly littoral invertebrates such as amphipods, gastropods and polychaetes. The evidence presented here strongly suggests that black bream larvae exploit resources found in the

water column above a strongly anoxic and saline layer. Anoxia in water deeper than 4 m prevents any utilisation of deeper habitats by all size classes of bream. At a length of approximately 15 mm, the free-swimming larval stage ends and juvenile black bream settle into shallow and fringing weed-beds where oxygen concentrations are higher.

The S.I. indices showed that there were some biologically significant overlaps in the diet of the various size classes, for example, between juvenile size classes < 20 mm and 20-40 mm TL and between 40-60 mm and above 60 mm TL, indicating a shift in juvenile diet above 40 mm (combined site data). This corresponds with the average length range (30-40 mm) recorded for the dietary shift from primary to secondary stage recorded in a variety of estuarine inhabiting juveniles of marine fish species (Carr 1973). However, in terms of ontogenetic shifts in diet, the trends in the S.I. data become more apparent if the arbitrary biological significance value of 0.6 is disregarded. When the diet of the smallest juvenile size class (< 20 mm) is compared to the diet of the each of the successively larger size classes (ie. > 20-40 mm, > 40-60 mm and > 60 mm), the S.I. values reduce, indicating less overlap in diet. This means that as juveniles become larger, they undergo a gradual shift in prey species away from those prey species exploited by smaller size classes. Viewed in this manner the changes in diet are more a 'gradual shift away' from the diet of small size classes rather than a particular event driven change, such as that which occurs between the planktonic larval phase and littoral juvenile phase of the species.

Intraspecific competition among size classes of larval and juvenile *A. butcheri* is minimised through the utilisation of different niches at different stages of the life cycle; this is evident both in the diet and in the distribution of the fish. Intraspecific competition among different size classes of juveniles is minimised through the targeting of different prey species in the littoral zone of the estuary. The underlying mechanism seems to be a function of variations in distribution, ie. in the case of larvae, they occupy different regions of the estuary, while the different size classes of juveniles seem to feed in different areas of the littoral zone (see above).

The conclusions drawn above are also supported by observations concerning distribution of fish and the physical and chemical properties of the estuary. Firstly, larvae appear to be entirely planktonic in this system. The marked halocline and highly anoxic deeper waters preclude these animals from utilising portions of the water column below the

halocline. Secondly, at a TL of approximately 10 mm, there is a marked shift in habitat requirements, the planktonic larval phase gives way to a juvenile littoral phase. *A. butcheri* move out of the water column and settle in the fringing littoral regions of the estuary. At the time the 10 mm larvae disappear from the plankton, juveniles of 10–18 mm appear in the littoral zones.

Gaughan (1991) has classified estuarine fish larvae into three groups based on diet: planktivores feeding on copepods (copepodivores), planktivores feeding on other groups when copepods are not abundant, and those feeding on fish larvae (chordativores). Piscivorous larvae are not common in estuaries (Gaughan 1991). *Acanthopagrus butcheri* is unusual in that whilst larvae <9 mm in length are copepodivores they become, at least partially, ichthyoplanktivores above 9 mm in length; juveniles <40 mm in length appear to revert to copepodivory.

A total of 45 different food items were recorded from the stomachs of juvenile fish in the present study. This wide range of diet items illustrated the opportunistic and flexible nature of the feeding in juvenile *A. butcheri*. A flexible diet which enables fish to switch from one prey item to another has important implications in an estuary, where the changing abiotic environment may affect the distribution and abundance of prey items (Miller & Dunn, citing Carricker 1967). The most successful estuarine fish species appear to be those with broad niches (Bennet 1990).

Weng (1970) identified the major diet items of *A. butcheri* > 15 cm in length collected from South Australian waters, as crabs and other crustaceans, tubicolous worms, cockles, brittle worms, gobies, and mussels. The absence of comparative information regarding the diet of juveniles in Weng's study makes it difficult to compare his observations to the results obtained in the present study. However, tubicolous polychaetes, molluscs, and crabs, which were the major diet items found in the stomachs of juveniles > 60 mm in this study have also been observed by the authors in the stomachs of adult *A. butcheri* collected from the Hopkins Estuary (unpublished data). Juveniles appeared to ingest the tentacular mantle of individual tubicolous worms, whilst adult *A. butcheri* ingested the entire tubes of several worms. This suggests that the diet of juveniles > 60 mm in length may overlap considerably with the diet of larger individuals.

There are many cases of ontogenetic changes diet similar to those described for juvenile *A. butcheri*, in the literature. For example, catfish (*Arius graeffei*), jewfish (*Johniops vogleri*), narrow

banded sole (*Aseragoddes macleayanus*) and threadfin (*Polynemus multiradiatus*) (Sumpton 1990), cardinal fish (*Apogon reupellii*) (Chrystal 1985), and two species of whiting (*Sillago sihama* and *Sillago analis*) (Gunn, 1985). Although ontogenetic changes in diet provide an ecologically efficient means of avoiding intraspecific competition, it is likely that these changes have arisen due to the inability of smaller fish to capture or ingest certain types of larger prey because of physical limitations in their feeding apparatus and mobility.

ACKNOWLEDGEMENTS

The authors thank John McKenzie, Bruce McCarragher and Ray Donald (all of the former Department of Conservation and Environment) for assistance in larvae collection, and Associate Professor John Sherwood (School of Aquatic Science and Natural Resources Management, Deakin University, Warrnambool) for juvenile samples. Chris Walsh and Vijaya Rajendram (both of the School of Aquatic Science and Natural Resources Management, Deakin University, Warrnambool) are thanked for assistance with data analysis. Gina Newton (Fisheries Section, Bureau of Rural Resources, Canberra) collected larvae and commented on the manuscript.

REFERENCES

- BENNET, B. A. & BRANCH, G. M., 1990. Relationships between production and consumption of prey species by resident fish in the Bot, a cool temperate South African estuary. *Estuarine, Coastal and Shelf Science* 31: 139–155.
- BLABER, S. J. M. & BLABER, T. G., 1980. Factors affecting the distribution of juvenile estuarine and inshore fish. *Journal of Fish Biology* 17: 143–162.
- BLABER, S. J. M., 1980. Fish of the Trinity Inlet system of north Queensland with notes on the ecology of fish faunas of tropical Indo-Pacific estuaries. *Australian Journal of Marine and Freshwater Research* 31: 137–146.
- BUTCHER, A. D., 1945. *Conservation of the Bream Fishery*, pp. 1–16. Fisheries and Game Department, Victoria, Melbourne.
- CARR, W. E. S. & ADAMS, C. A., 1973. Food habits of juvenile marine fishes occupying seagrass beds in the estuarine zone near Chrystal River, Florida. *Transactions of the American Fisheries Society* 102: 511–540.

- CHRYSTAL, P., POTTER, I. C., LONERAGAN, N. R. & HOLT, C. P., 1985. Age structure, growth rates, movement patterns and feeding in an estuarine population of the cardinalfish *Apogon rueppellii*. *Marine Biology* 85: 185-195.
- DAY, J. W., JALL, C. A. S., KEMP, W. M. & YANEZ-ARANCIBIA, A., 1989. *Estuarine Ecology*. John Wiley & Sons, New York, 559 pp.
- GAUGHAN, D. J., 1991. Feeding by estuarine and marine fish larvae. In *Larval Biology*, Vol. 15, pp. 37-40, D. A. Hancock, ed., Bureau of Rural Resources, Canberra.
- GUNN, J. M. & MILWARD, N. E., 1985. The food, feeding habits and feeding structures of the whiting species *Sillago sihama* (Forsskaal) and *Sillago analis* Whitley from Townsville, North Queensland, Australia. *Journal of Fish Biology* 26: 411-427.
- LENANTON, R. P. & POTTER, I. C., 1987. Contribution of estuaries to commercial fisheries in temperate Western Australia and the concept of estuarine dependence. *Estuaries* 10: 28-35.
- MCCARRAHER, D. B., 1986. *Distribution and abundance of sport fish populations in selected Victorian estuaries, inlets, coastal streams and lakes. 4. Portland Region*, pp. 1-28. Fisheries Division, Victorian Department of Conservation and Environment, Melbourne.
- MILLER, J. M. & DUNN, M. L., 1982. Feeding strategies and patterns of movement in juvenile estuarine fishes. In *Estuarine Comparison*, pp. 437-448, V. S. Kennedy, ed., Academic Press, New York.
- POLLARD, D. A., 1976. The biology of a landlocked form of the normally catadromous salmoniform fish *Galaxias maculatus* (Tenyns). *Australian Journal of Marine and Freshwater Research* 34: 805-811.
- POTTER, I. C., LONERAGAN, N. R., LENANTON, R. C. J. & CHRYSTAL, P. J., 1983. Blue-green algae and fish population changes in a eutrophic estuary. *Marine Pollution Bulletin* 14: 228-233.
- RUSSEL, D. J. & GARRET, R. N., 1983. Use by juvenile barramundi, *Lates calcarifer* (Bloch), and other fishes of temporary habitats in a tropical estuary in northern Australia. *Australian Journal of Marine and Freshwater Research* 34: 805-811.
- SCHOENER, T. W., 1970. Nonsynchronous spatial overlap of lizards in patchy habitats. *Ecology* 51: 408-418.
- SHERWOOD, J. E. & BACKHOUSE, G. N., 1982. *Hydrodynamics of salt wedge estuaries—implications for successful spawning in black bream (Acanthopagrus butcheri)*, pp. 1-5. Warrnambool Institute of Advanced Education, Warrnambool.
- SLOANE, R. D., 1984. Distribution, abundance, growth and food of freshwater eels (*Anguilla* sp.) in the Douglas River, Tasmania. *Australian Journal of Marine and Freshwater Research* 35: 325-339.
- SUMPTON, W. & GREENWOOD, J., 1990. Pre- and post-flood feeding ecology of four species of juvenile fish from the Logan-Albert estuarine system, Moreton Bay, Queensland. *Australian Journal of Marine and Freshwater Research* 41: 795-806.
- WENG, H. T., 1970. *The black bream, Acanthopagrus butcheri (Munro); its life history and its fishery in South Australia*. Masters Thesis, University of Adelaide, pp. 1-97.